

Prologue

## Small Business Innovations

*A special research and development program for small businesses is expanding their participation in aerospace technology development and transfer*

The Small Business Innovation Research (SBIR) program was established by Congress in 1982. Its dual objectives were to increase participation of small businesses in federal high technology research and development activities, and to stimulate conversion of government-funded research into commercial applications. The program has been eminently successful in attaining both objectives.

Each technology-generating federal agency that has an extramural R&D budget of more than \$100 million annually is obliged to set aside one and one-quarter percent of those funds for SBIR projects. There are 11 such agencies, each administering its own program independently under policy guidelines set by the Small Business Administration.

NASA's SBIR program has been particularly successful, both for NASA and the nearly 800 small businesses involved. The program provides NASA an additional source — beyond traditional aerospace companies — of R&D talent and innovative thought. Hundreds of new systems and components that advance NASA's capability for aerospace research and operations have emerged from the SBIR



Pictured in a laboratory environment is a Femtometrics Model 200-1 SAW Mass Microbalance (foreground) developed under the NASA Small Business Innovation Research program. The microbalance is a highly sensitive instrument for detecting dust particle concentrations in clean rooms, measuring aerosols in the upper atmosphere, or monitoring the presence of toxic vapors in industrial environments.

program. Similarly, NASA/SBIR contracts give small businesses an opportunity to hone their developmental skills and expand their technological capabilities.

There is another beneficiary: the U.S. economy, which benefits from the jobs created and the contributions to the nation's Gross National Product that result when an SBIR project generates a spinoff commercial application. In NASA's SBIR program, spinoffs have resulted in about one of every three projects completed.

A NASA/SBIR project starts with a proposal by the small business, in response to NASA's annual solicitation, for development of a novel idea or



concept. The agency evaluates the proposal from the standpoint of potential usefulness to NASA and the potential for becoming a commercial product or process. The best concepts are rewarded with six-month Phase I contracts for up to \$50,000, under which the company determines the technical feasibility of the innovation it has proposed.

Phase II contracts are awarded competitively from proposals — submitted by Phase I contractors — that include the results of Phase I research; about half of the Phase I projects continue into Phase II, which can run as long as two years and be funded up to \$500,000.

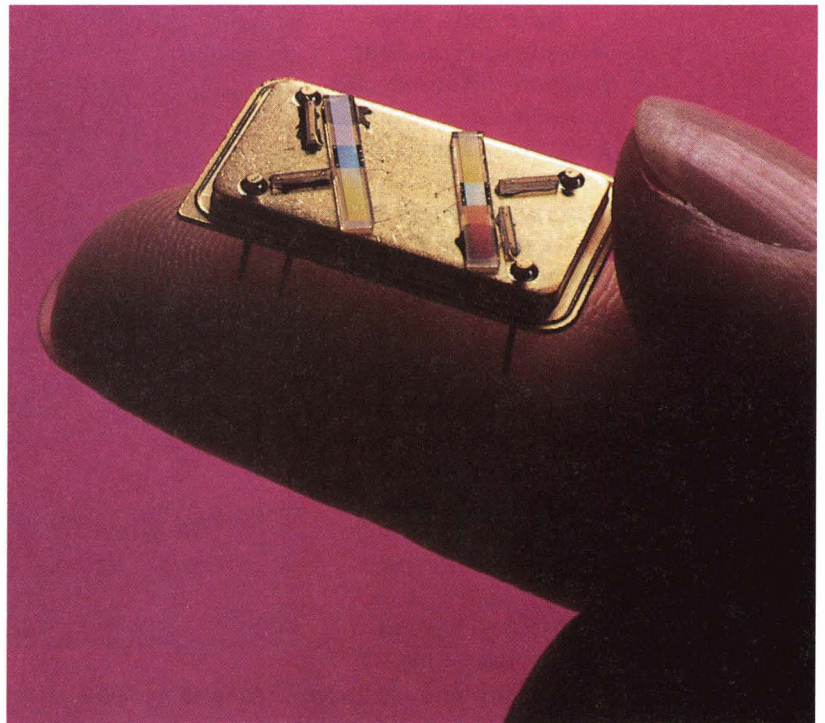
In Phase III, the small business participant may apply the results of Phase I/II research to development of a product or process for the commercial market, using private capital to do so. Phase III may also involve NASA's continued development and purchase for its own use of the products of Phase II — but NASA may not use SBIR set-aside funds for such purposes.

A NASA/SBIR project conducted by Femtometrics, Costa Mesa, California illustrates how a company conceived and developed an advanced instrument for government research, then adapted the same technology to creation of a commercial product of importance in the industrial workplace.

Since 1979, Langley Research Center has been using a NASA-developed instrument known as the QCM (short for quartz crystal microbalance cascade impactor) for collection and measurement of aerosol particles in the upper atmosphere. The system detects aerosols — tiny solid particles or liquid droplets — that collect on the quartz crystal, segregates them in 10 size categories and weighs them, providing information to environmental researchers on the size distribution and mass concentration of aerosols in the atmosphere.

Femtometrics responded to NASA's SBIR solicitation with a proposal for an advanced, much more sensitive aerosol detector to meet a perceived need for measurement of extremely low concentrations of aerosols and detection of sub-micron particles in clean rooms where aerospace systems are assembled. The proposal won Femtometrics a Langley Research Center Phase I SBIR contract and the results led to Phase II development of the instrument.

The resulting product is described as "the next generation of aerosol mass microbalance



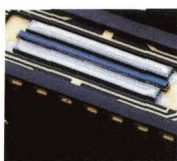
technology," an instrument of extreme sensitivity due to use of a new type of sensor, the surface acoustic wave (SAW) piezoelectric crystal. It offers a mass resolution two orders of magnitude greater than the crystal in the QCM.

Femtometrics used the technology to develop a commercial product, the Model 200-1 SAW Mass Microbalance, which provides a 400-fold increase in mass sensitivity per unit area over the conventional bulk crystal microbalance. The instrument can be used for real-time particle monitoring in clean rooms. It also has utility in measurement of chemical vapors in very low concentrations; the SAW crystal is coated with a thin chemical film that reacts with and detects the particular vapor. This provides a means of measuring target chemicals in the stratosphere that are of interest to environmental researchers because of the key roles of these chemicals in climate and stratospheric chemical composition. The same technology enables detection of toxic chemicals in the industrial environment; the small size, low cost and high sensitivity of the Model 200-1 SAW Mass Microbalance makes the instrument attractive for use as an industrial toxic vapor monitor.

Shown above is the fingernail-size sensor unit located in the cylinder atop the instrument; it is actually two separate crystals, one the active sensor, the other a reference.

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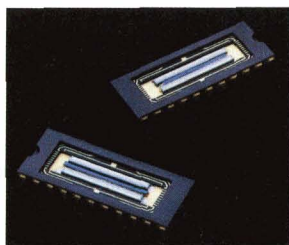
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Since 1983, when NASA initiated its SBIR program, the agency has sponsored more than 1,500 Phase I projects handled by 765 companies; by mid-1991, 632 of those projects had proceeded into Phase II with 377 firms participating.

NASA has obligated a total of \$348 million for SBIR contracts, which are managed by NASA field installations as part of their overall R&D activities. Nearly 300 Phase II projects have been completed and roughly half of the innovations produced have been used in NASA programs or are planned for use. The bottom line, from the standpoint of economic benefit, is that about a third of the completed projects have generated commercial applications.

Here are some examples:

SBIR work by Epitaxx, Inc. led to commercial development of these high performance infrared photodetectors for remote sensing, fiber optics and other applications.

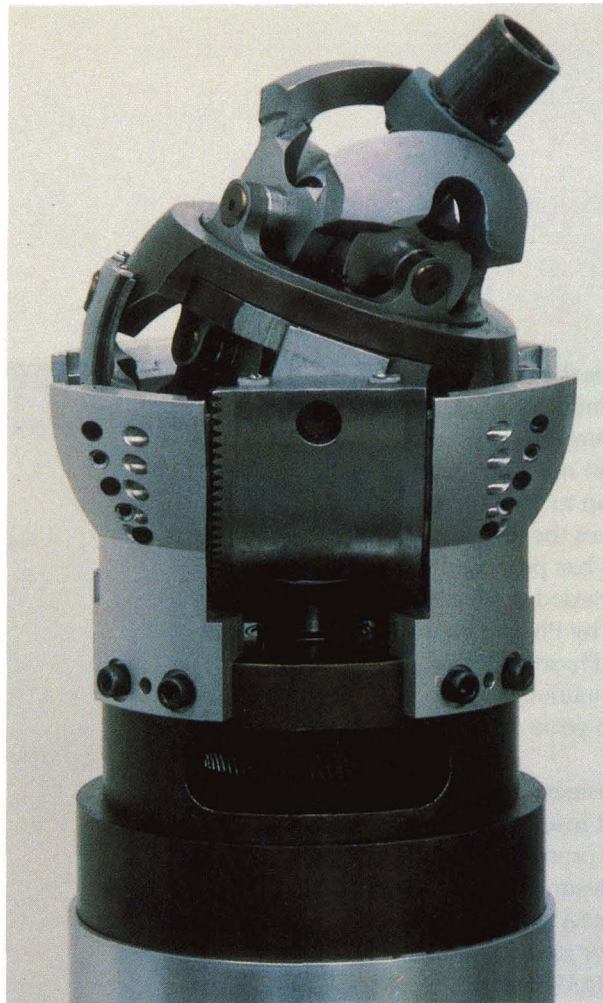


Ross-Hime Designs, Inc., Minneapolis, Minnesota developed what company literature calls "the first successful singularity-free high-precision (robotic) wrist." Singularity is a phenomenon of robotics that can cause a joint to

jam as it attempts to move in an area where it has no axis of rotation or range of motion; singularity can cause damage to equipment or tooling.

Under a Langley Research Center SBIR contract, Ross-Hime developed a commercially available Omni-Wrist™ actuator, which has a 25-pound capacity, 180 degrees of pitch/yaw and 360 degrees of roll (another version, Omni-Wrist II, offers a 100-pound load capacity and the same range of motion). Applications include spray painting, sealing, ultrasonic testing, welding and a variety of nuclear industry, aerospace and military uses.

Epitaxx, Inc., Princeton, New Jersey received a Goddard Space Flight Center SBIR contract to



Ross-Hime Designs, Inc. developed the Omni-Wrist robotic arm with humanlike dexterity and greater-than-human range of motion.

develop a linear detector array for satellite imaging applications. The array employs indium-gallium-arsenide alloys and can operate at room temperature; earlier detectors have to be cooled to extremely low (cryogenic) temperatures and that is both difficult and expensive.

Epitaxx used the same technology to create a series of commercial products, including the Epitaxx Near Infrared Room Temperature Indium-Gallium-Arsenide

Photodetectors. The basic device is a photodetector that provides an electrical signal when it is exposed to a scene that radiates energy in the near infrared. It has applications as a laboratory tool for generating optical spectra, and for remote sensing, fiber optic and laser position-sensing applications.



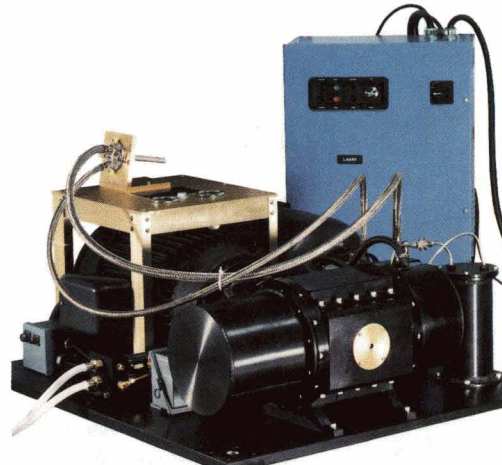
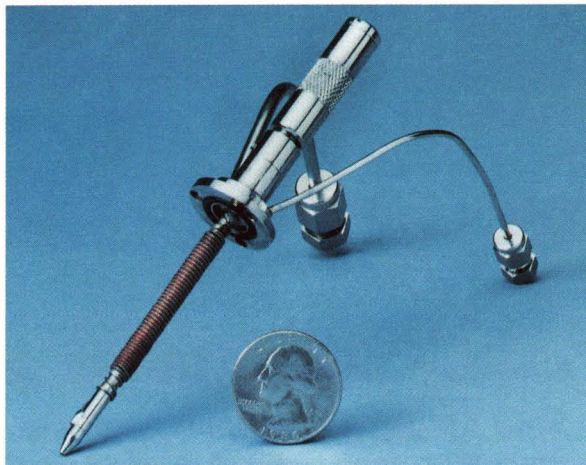
Products of SBIR research by Scientific Materials, Inc. are these crystal components for solid state lasers.

For Kennedy Space Center, General Pneumatics Corporation, Scottsdale, Arizona developed a special Joule-Thomson (JT) expansion valve that is far less susceptible to clogging by particles or condensed contaminants in the flow than are conventional JT valves. The company employed the technology in a commercial anti-clogging cryostat that liquefies gases by expansion from high pressure through a nozzle to produce cryorefrigeration. The cryostat is combined





An employee of Lightwave Electronics is holding a Series 122 MISER ring laser, which has applications in fiber sensing, communications and laser radar.



General Pneumatics Corporation's participation in a NASA SBIR project resulted in two commercial products: a non-clogging cryostat (left) to liquefy gases for extremely low temperature cryorefrigeration, and the cryocooler (right) used to generate cryogenic cooling for infrared sensors, superconductors, supercooled electronics and cryosurgery.

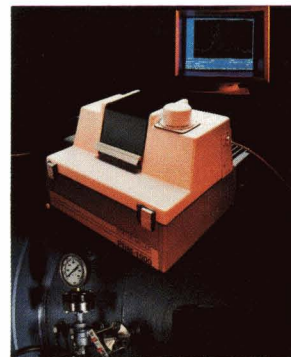
with the company's non-contaminating compressor in another General Pneumatics commercial product, a closed cycle Linde-Hampson cryocooler used to generate cryogenic cooling for infrared sensors, superconductors, supercooled electronics and cryosurgery.

Lightwave Electronics Corporation, Mountain View, California, received an SBIR contract from Jet Propulsion Laboratory for a Prototype Laser Diode-pumped Solid State Transmitter. The company delivered a low noise ring laser with voltage tuning that could be used as a local oscillator in an optical communications system. The voltage tuning feature allows "phase-locking" the lasers, making them "electronic", similar to radio and microwave electronic oscillators. From this technology, Lightwave developed the Series 120 and 122 non-planar diode pumped ring lasers for applications in fiber sensing, coherent communications and laser radar.

Foster-Miller, Inc., Waltham, Massachusetts, in SBIR cooperation with Langley Research Center, developed the first analytical system capable of directly measuring the chemistry of advanced composite materials. It employs an infrared fiber optic sensor, embedded in the composite material, to track the molecular vibrational characteristics of a composite part while it is being cured in a press or an autoclave. Thus, says a company official, it "provides first hand information about chemical reactions as opposed to measuring a secondary change." The patented In Situ Fiber Optic Polymer

Reaction Monitor, which won a 1990 R&D 100 award, could lead to significantly higher yields in the manufacture of complex composite parts, with consequent reduction in cost. It is expected to find broad research and commercial utility in aerospace, industrial and environmental applications.

Scientific Materials Corporation (SM), Bozeman, Montana, under a Langley SBIR contract, developed a SciMax™ line of improved Nd:YAG crystals for laser and electro-optic applications (Nd:YAG is short for the materials involved — neodymium, the dopant, with yttrium aluminum garnet). SM's research provided a process for producing uniform laser rods in which the amount of water trapped in the crystal during growth is reduced, thereby improving efficiency, and the properties that affect optical quality are also improved for a further gain in crystal efficiency. SM is producing the crystals for the commercial market; applications include fiber optics, telecommunications, welding, drilling, eye surgery and medical instrumentation.



An award-winning innovation by Foster-Miller, Inc. is a technique and a system for monitoring chemical reactions in composite materials while they are undergoing cure in a press or autoclave.

™Omni-Wrist is a trademark of Ross-Hime Designs, Inc.

™SciMax is a trademark of Scientific Materials Corporation.